Pearson Edexcel

# Examiners' Report
# Principal Examiner Feedback

## January 2025

Pearson Edexcel International Advanced Level
In Further Pure Mathematics F2 (WFM02)
Paper 01

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## Summary

This paper proved to be accessible to all candidates, while providing sufficient challenge to the more able. There were lots of marks available for standard techniques, as well as some marks that were harder to achieve.

Questions 5(b), 7(b)(c) and question 8(c) proved to be more challenging for some candidates. A lack of working was also seen in some candidates' work which requested a specific technique to be applied, such as the method of differences in question 4 (b). There were four 'hence' type questions in this paper, and it was pleasing to see that most candidates recognised this and applied their previous work when attempting the subsequent parts that requested this. Some candidates provided solutions to questions which, although sometimes mathematically correct, presented obtuse arguments that were difficult to follow, and not always aligned with the specification being examined.

## Question 1

This question proved to be successful for most, with many fully correct solutions seen. The integration factor method was clearly well practised.

Part (a) proved very straightforward to most candidates, though a few did stumble even at this early stage. Most candidates progressed to $\exp(-3\ln\sec x)$ or $\exp(3\ln\cos x)$ and demonstrated the exp and ln being correctly processed. Only a handful of candidates attempted to justify the integration factor by differentiating $y\cos^3 x$ and factorising $\cos^3 x$. Very few candidates showed insufficient working to gain both marks in this part.

In part (b) it was pleasing to see that most candidates understood and could apply the integration factor method and progress to an integrable form. Common errors amongst the incorrect integrations seen here were in integrating the resulting $\cos x$ to $-\sin x$. Some candidates did not apply the boundary conditions to obtain a value for the constant of integration, but most attempts did this sucessfully, and progressed to a correct final form. It was rare to see a final solution not in the form $y = \cdots$

**Question 2**

This question proved to differentiate amongst all candidates, with most scoring full marks in part (a), but full marks in the remaining parts proving hard to achieve for many. When solving the inequalities, many candidates resorted to looking at both sides of the asymptote, with tables of sign or sketches seen to establish the correct region. It was also evident that some candidates had used graphical calculators in (b) and (c), but the scaffolding provided in the question, and the requirements needed to score method marks meant that most candidates were able to achieve the majority of the marks available.

In part (a) most candidates cross multiplied and progressed to the correct quadratic that was successfully solved. Some resorted to overly obtuse methods such as multiplying both sides by $(x^2 + 1)(x + 4)^2$ and progressing to a factorised cubic. These attempts usually resulted in the correct points of intersection being found, but in the form of the critical values which also included the -4 and resulted in the final mark being withheld if this was not discounted. Exact values were usually given in the simplest form, but $x = \frac{-8 \pm \sqrt{68}}{2}$ was seen. It would be adviseable to remind candidates that they should quote a correct quadratic formula and show the substitution of values, as errors when typing into a calculator with no quadratic formula quoted could result in no method mark being awarded for solving.

In part (b) candidates were able to score at least one mark for obtaining the correct form of the solution for one inequality, provided that their roots were on opposite sides of the asymptote. Some candidates produced overly complex algebraic solutions which would have been better resolved by consideration of a sketch or a table of sign.

Part (c) was equally accessible to all with one method mark being available for a partially correct range which included the reflected part of the reciprocal graph. The second mark proved hard to obtain with many incorrect responses seen. Once again, a table of sign would have proved beneficial for many, as some candidates resorted to producing unecessary algebra to find the solution set. For a two mark question, candidates would be advised to use more efficient methods to save time for trickier questions later in the paper. In both parts (b) and (c) it was uncommon to see candidates using set notation.

**Question 3**

This question had lots of accessible marks for routine work at this level, and many candidates were able to correctly process the differential equation by differentiating to achieve a 3rd derivative of the correct form.

In part (a) the first two marks were almost universally scored for a correct value for the 2nd derivative at the initial conditions given in the question. A generous second method mark was then awarded for some attempt at the product rule on one term, which was usually achieved. The second accuracy mark was then given for the correct form of the $y\frac{dy}{dx}$ term progressing from $y\frac{\mathrm{d}y}{\mathrm{d}x} \to y\frac{\mathrm{d}^2y}{\mathrm{d}x^2} + \left(\frac{\mathrm{d}y}{\mathrm{d}x}\right)^2$. Errors with this term meant that candidates did not score the final two marks in part (a) as the final expression for the 3rd derivative was incorrect, and the value of the 3rd derivative was also incorrect. However this question did not involve complex forms with both the product and the chain rule, as is common in this type of question, and the first three marks were designed to be attainable to most candidates. It was extremely rare to see candidates substitute their 2nd derivative expression into their 3rd derivative expression in part (a).

Part (b) was pleasingly successful, with very few incorrect attempts using incorrect forms of the Taylor series formula, or incorrect attempts with no formula quoted. Candidates should be advised that it is always better to quote a correct Taylor series formula and then substitute their values, as errors with substitution, such as misreading, with no formula quoted, could result in no method mark being awarded. This question asked for the series expansion of $y$ and some candidates lost the final mark for using $f(x) = \cdots$ when $f(x)$ had not been adequately defined.

**Question 4**

This question was standard material for this paper, and there were many fully correct responses seen. However some candidates struggled to cope with three terms in the summation, while others resorted to methods that did not convey the application of the method of differences, or that progressed to a correct form with no justification and/or without using part (a). Such attempts accrued zero marks in (b), as the ‘hence’ and/or the stipulated method had not been used.

In part (a) most candidates were able to progress to the correct partial fraction form, with multiplying denominators and substituting values or comparing coefficients the most common and effective method seen. Some candidates used the cover up method for obtaining values but this was less common. Others obtained partial fractions which were not a full partial fraction decomposition, such as $\frac{r+4}{r(r+1)(r+2)} \equiv \frac{A}{r(r+1)} + \frac{B}{(r+1)(r+2)}$ but these were often revised to the full decomposition with linear factors on the denominator in part (b) once the method of differences for the summation was attempted. Overall it was rare for candidates not to score full marks in part (a).

In part (b) the method of differences was requested, but candidates needed to show sufficient working to show clearly that this method had been employed. Those who were well practised in this technique were able to identify the pattern very quicky and isolate the non-cancelling terms. Some attempts were seen that could have scored more marks, but candidates resorted to poor layout such as listing the terms in the summation horizontally rather than vertically which made the non-cancelling terms more difficult to identify. Candidates should be advised to always show evidence of cancelling terms, as some partial attempts did not accure the first method mark in (b) even after listing correct terms, as insufficient cancellation was seen on the diagonal. If the correct non-cancelling terms were seen, it was unusual to see anything other than full marks being scored. Poor algebra was not common, as was working with $'r'$ instead of $'n'$. Some resorted to rewriting their partial fractions as $\frac{2}{r} - \frac{2}{r+1} + \frac{-1}{r+1} + \frac{1}{r+2}$ and then using two separate summations of two terms- which was as equally successful as the former (main) approach on the mark scheme.

**Question 5**

This question provided a good level of differentiation amongst all candidates, but the given identity rendered part (a) accessible to all candidates. Problems with standard A level Mathematics integration proved to be probematic for a significant number of candidates, while those who chose overly obtuse methods in (b) found full marks harder to achieve.

In part (a) the vast majority of candidates used the given identity to arrive at a simple trigonometric function for $r \sin\theta$ which was successfully differentiated and solved to find the correct theta value. Sign errors and choosing the incorrect argument were relatively rare, and the given diagram helped candidates to choose the correct theta value. Some candidates did not apply the given identity and ended up with a more complex function to be differentiated. Those who started with $y = r\sin\theta =$

$\sqrt{3}\sin\theta + \tan\frac{\theta}{2}\sin\theta$ were usually able to differentiate successfully, with the occasional slip with the $\frac{1}{2}$ in the resulting $\sec^2\frac{\theta}{2}$ but many encountered more problems when attempting to solve to find theta. Invariably this involved re-writing their expression in terms of sine and cosine terms to achieve $\sqrt{3}\cos\theta+\cos\theta\frac{1-\cos\theta}{\sin\theta}+\frac{1}{2}\sin\theta\left(1+\frac{(1-\cos\theta)^2}{\sin^2\theta}\right)=0$ which was a far more complex expression to deal with successfully. Others started with the same expression but re-wrote their derivative in terms of $\tan\frac{\theta}{2}$ terms to achieve a quadratic in tan- but once again this was far more challenging to contend with than the indended expression obtained when using the given hint in the question.

Part (b) proved to be equally (perhaps unecessarily) challenging for many, due to the overly complex approaches employed. Candidates who used the identity $\tan^2\frac{\theta}{2} \equiv \sec^2\frac{\theta}{2} - 1$ were invariably more successful than those who didn't, and it was evident that some candidates were not familiar enough with the standard integrals required to progress to the correct result. The most common alternative approach was for candidates to use the identity given in (a) to replace the $\tan^2\frac{\theta}{2}$ with the square of the given identity and then achieve terms of the form $\text{cosec}^2\theta - 2\text{cosec}\theta\cot\theta + \cot^2\theta$ but this required further simplification using the identity $\cot^2\theta + 1 = \text{cosec}^2\theta$ before a fully integrable form was reached. Another overly complex approach was used to also replace the $\tan\frac{\theta}{2}$ term with $\frac{1-\cos\theta}{\sin\theta}$ and progress to additional terms involving $\ln|\text{cosec}\, x + \cot x|$ and $\ln|\sin x|$. Candidates who used these methods, and managed to progress to a correcly integrated expression, often found problems when evaluating the integral between the given limits as the lower limit led to an indeterminate form, which could be resolved with an appropriate treatment of limits using, for example, L'Hopitals rule- but this was outwith the specification for this unit, and most candidates were therefore unable to achieve full marks if one of these obtuse methods was used. It would be adviseable for candidates to be familiar with the standard integrals available on the formula booklet, as well as standard trigonometic integration covered in previous units

**Question 6**

This question was, as is usually the case in this paper, a chance for all candidates to demonstrate the application of a standard technique to solve a second order differential equation. Candidates should be reminded that choosing overly complex (even if mathematically correct) methods carries the risk of marks being deducted for lack of transparency, especially if the method employed is not a standard technique covered in the specification.

Part (a) was standard work at this level and provided very few difficulties for most candidates. The simple form of the PI rendered the resulting differentiation and work to find their constant trivial and many fully correct solutions were seen. The most common error was for the incorrect form of a PI being used, with the most common incorrect ones seen used being $kxe^{5x}$ or $kx^2e^{5x}$ which led to incorrect or inconsistent work being seen to obtain a value for their constant $k$. Unfortunately some reponses with mixed variables were seen, with confusion around the form of the complementary function, but if these were recovered to a fully correct form then full marks could still be scored. Final solutions that did not have $y = \cdots$ lost the final mark, or those that had mixed variables but were otherwise correct. Some candidates used $y = Ae^{\left(\frac{1}{2}+3i\right)x} + Be^{\left(\frac{1}{2}-3i\right)x}$ for the complementary function and then differentiated this form in part (b). Other forms of the complementary function were possible, but candidates should be reminded to use the simplest form of the complementary function to make their subsequent work easier, but also to allow examiners to follow their methods.

Part (b) proved to be slightly more problematic for some candidates, but most were able to achieve at least the first method mark for using the initial conditions to find one constant. Errors with the subsequent differentiation required to obtain the second method mark were rare and most could progress to a correct final particular solution. Some candidates lost accuracy marks here for mixed variables once again, but technical accuracy is required in routine questions which require the application of a standard technique. A very small number of candidates differentiated the exponential form of the complementary function and used the initial conditions to obtain complex values for their constants, which was again an overly obtuse method and not part of the specification. Those who employed this method were usually very able candidates who proved to be successful with this approach, but this approach is strongly discouraged.

**Question 7**

This question proved to be a challenge for many candidates, with marks lost through lack of justification, poor notation, and/or a failure to fully utilise the previous parts of the question in part (c). Part (b) was very poorly attempted, and candidates should be reminded that printed answers need to be justified fully with correct intermediate work shown.

Part (a) was a standard application of De Moivre's theorem and most candidates had a good idea of how to proceed. Carelessness with the binomial expansion or simplifying the powers of i incorrectly were some of the reasons for the 2nd method mark being withheld, but most candidates were able to score at least the first two marks in (a). Showing fully correct work to progress to the printed answer proved to be more problematic for some, with missing arguments, inconsistent i terms or incorrect statements leading the penultimate A mark being deducted. Part (a)(ii) was more successful with most candidates scoring the A mark, but carelessness with missing arguments etc was condoned here if already penalised for the previous mark.

Part (b) was very poorly attempted, with many candidates going from

$$\tan 5\theta = \frac{\sin 5\theta}{\cos 5\theta} = \frac{5\cos^4\theta \sin\theta - 10\cos^2\theta\sin^3\theta + \sin^5\theta}{\cos^5\theta - 10\cos^3\theta\sin^2\theta + 5\cos\theta\sin^4\theta}$$

directly to the printed answer with no suporting working. 'Show that' questions require full justification and candidates needed to show some intention to progress from the latter to the printed answer e.g. dividing the top and the bottom by $\cos^5\theta$ or equivalent work, but this work needed to be shown. Some candidates stated 'divide by $\cos^5\theta$' followed by the printed answer which was too vague to imply the correct method.

Part (c) proved to be problematic for some candidates, but most were able to score at least the first few marks for recognising that the given equation was an adaptation of that in part (b) with $x = \tan\theta$. Most candidates were then able to arrive at a correct value for $\theta$ but several listed five values for $\theta$ and stopped. It was also common to see candidates list one correct value for $x$ and then stop, or to offer some values of $x$ which did not follow their previous work. Candidates were given credit for undoing the substitution to arrive at one correct value for $x$ from their work, even if their $\theta$ value was incorrect. The final two marks proved hard to achieve for many, with rounding errors, partially correct values and/or missing values for $x$. This question stipulated that candidates had to use the previous part of the question and to show all stages of their work, so it was disappointing to see some candidates simply write down values for $x$ which had clearly been obtained from a graphical calculator. Such attempts received no marks.

**Question 8**

In general this question provided a good level of differentiation amongst all candidates, with those who were less proficient in standard techniques such as comparing real and imaginary parts, finding magnitudes or simplifying the resulting algebra when multiplying by the complex conjugate stuggling to score all the marks available. Part (c) was well attempted, suggesting that candidates did not find the paper too long, but full justification was not forthcoming for the arguments given, which suggested that there was an element of guesswork involved. It was noted that this question prompted some attempts involving inversion theorems of mobius transformations and transforming points. These methods, while mathematically correct, are not part of the specification this examination is designed to test and are strongly discouraged. Therefore they do not feature in the main mark scheme published to centres.

Part (a) was interesting as a lot of canidates deviated from the main scheme here, by beginning with re-arranging the given transformation to make $z$ the subject and then attempting to multiply by the complex conjugate. For many the resulting algebra proved too burdensome and this was the only mark they scored. Candidates who persevered with this method were usually successful by equating their imaginary part equal to 0 and simplifying the resulting expression to obtain the correct printed answer. Candidates who used the main mark scheme method were usually successful, but some did not provide sufficient working to demonstrate that their real and imaginary parts combined to give the printed answer. Candidates should be reminded that full justification is required for all stages in a 'show that' question- even if the step seems completely obvious. Very few candidates used the second alternative method given on the mark scheme by finding two expressions for $x$ and then equating them.

Part (b) provided an opportunity for candidates to score marks for a previous attempt at making $z$ the subject of the given transformation, if used in part (b). Most were then able to apply the modulus condition and attempt to find the magnitude of both sides of their equation, but inevitably some candidates struggled to deal with the resulting algebra. It was rare to see a proper attempt using perpendicular bisectors, but it was evident that some candidates recognised this to be a clear case of the required line being a perpendicular bisector, with some drawing diagrams and labelling the line with no algebraic justification.

Part (c) proved partially successful for a lot of candidates, with many able to score the 2nd M and first A marks for finding the argument of the image of the real axis given in part (a). Many were also able to score the first M mark for finding the argument of their line in part (b). However most candidates gave no justification for the required range of arguments that would satisfy the given conditions, with many stating the correct range but with guesswork being involved. Candidates were expected to check, by testing a point or otherwise, which side of the lines the image of a point inside the semi-circle with radius 2 and positive imaginary part, are mapped to under T. Some bypassed this necessity by using the condition that Im z > 0 in their imaginary part for $z$ to **show that** $v > -\frac{1}{\sqrt{3}}u$ and $|z| < 2$ in their expression for z to **show that** $v > \sqrt{3}u$ but this was rare.

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